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## A SIMPLE DAYLIGHT PHOTOMETER

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A need for a simple daylight photometer has long been felt, especially in the work of the undergraduate laboratory. The impossibility of making determinations of color sensitivity even with a degree of precision that is acceptable in undergraduate work without constancy of illumination especially when pigment papers are used as stimuli is too well known to need more than mention here. To make such an instrument broadly serviceable the following are some of the requirements which should be met. (a) The instrument should be compact and easily portable. (b) It should be so simple and inexpensive in construction as to be readily within the mechanical resources of the average laboratory. And (c) the standard and comparison fields should present little if any color difference.

An instrument which we have constructed especially to meet the above needs is shown in Fig. I. It has been in use in our laboratory for more than a year and has proven so serviceable and convenient that we have thought it worth describing for the possible benefit of others. It was designed and has been used by us primarily for the reproduction of a given intensity of illumination rather than for its measurement in photometric units, although it can be calibrated and be used for photometric measurements. The instrument consists of a photometer head, a short bar, a standard tungsten lamp with carriage which is moved back and forth along the bar by means of a rack and pinion, a millimeter scale which may be read outside of the photometer box, a finely graduated ammeter to regulate the supply of current to the lamp, and a tripod support. When operated as a daylight photometer one opening of the photometer head, the bar, and the standard lamp with its sliding carriage must be boxed in; and the other opening of the photometer head be suitably exposed to the illumination that is to be balanced against the light of the standard lamp. This boxing can be made as elaborate as one chooses or it can be made very simple. In this connection the different needs that may arise for a portable photometer

should be kept in mind. One may want, for example, to determine the average illumination, or the distribution of light in a room which may or may not be evenly illuminated. To do this the room should be laid out in small squares and measurements be taken in several directions of horizontal, vertical and 45 degree components of illumination at the corners of these squares. For such work it is obvious that a somewhat elaborate photometer is required, comprising, for example, a test plate that can be turned in different directions and a type of boxing that will permit of a quick adjustment of the lamp and reading of the scale from the outside. Such a photometer we are required to employ for the specification of the lighting effects in our work on the effect of different conditions of artificial lighting on the eye. An instrument of this kind, however, may cost from one hundred and fifty to three hundred dollars, which is of course more than is justified for the work of the general laboratory. If, however, an instrument is wanted primarily to reproduce the horizontal component of illumination or the light falling on a vertical surface such as a campimeter screen, rotating disk, etc., at a given point in a room, a very simple boxing is all that is required; for all that is needed here is to set the standard light at such a position on the bar as will balance the light in the room at that point and keep it there as long as that intensity of light is wanted. We have found it quite sufficient in one instrument we are using to make this boxing of light-proof cloth sliding on a suitably constructed frame. This cloth may be folded back to the far end of the frame for the adjustment of the position of the lamp or it may be brought forward and hooked to the frame of the photometer head while the photometric balance is being made. In case of the instrument described in this paper a somewhat more elaborate but still simple boxing is used. This boxing is made of heavy sheet tin painted black outside and inside and carefully light-proofed. It is 18 inches long, 4.5 inches wide, and 10 inches deep.<sup>1</sup> The photometer head forms one end of this box; the other end is of fiber fitted with binding posts which connect with the line and with cords running to the standard lamp, and with a knife switch to make and break the circuit. The

<sup>1</sup> It may seem that the boxing of this instrument is unnecessarily deep. It was made deep in order that lamps of ordinary sizes might be used as standards. The boxing shown in Fig. II is designed to take 25, 40, and 60-watt Mazda lamps and to allow for the adjustments of height needed to bring the centers of their filaments in line with the center of the opening of the photometer head. If smaller special lamps were used so much depth would not be needed and the instrument could be given a neater appearance.

top of the box is covered with tightly fitting hinged lid which permits of a convenient and easy entrance to the box. Projecting through the side of the box is a milled head which operates the rack and pinion adjustment of the position of the standard lamp on the bar. The instrument with the box ing is shown in Fig. II.

The photometer bar is 24 inches long. At one end of this bar is a right-angled holder for the photometer head. The

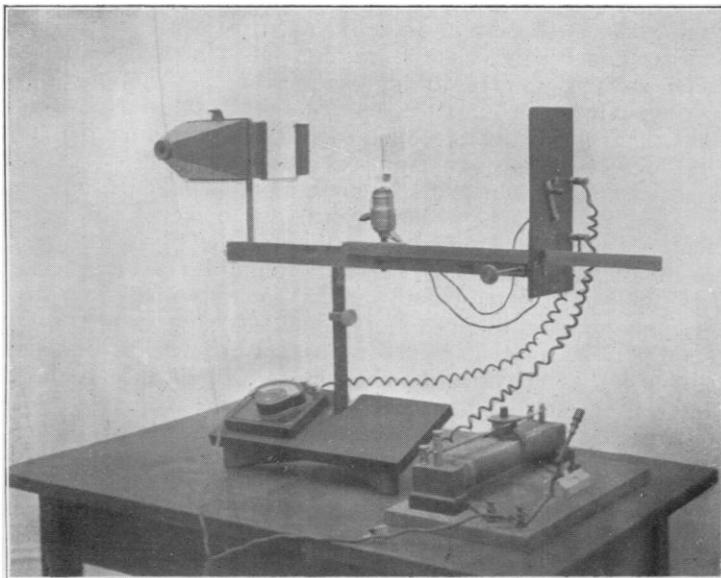


FIGURE I

photometer head is supported on a brass rod 5 inches long which passes vertically through an opening in the right-angled holder. When adjusted to the height that is wanted it is held in position by means of a set screw. The carriage for the standard lamp is shown in Fig. I. This carriage is fitted also with a right-angled holder and set screw to hold the standard lamp and to provide for adjusting its height so that the center of the lamp may always be in line with the center of the adjacent opening in the photometer head. On the bottom of this carriage is fastened a rack 12 inches in length which is engaged by the pinion operated by the milled head already mentioned. To this carriage is also fastened a brass scale graduated in millimeters which extends through

an opening in the fiber plate forming the end of the photometer box opposite to the head. Thus as the lamp is run back and forth along the bar its position can be read, outside the box, from the divisions on the scale. To facilitate the reading of these divisions the scale runs immediately back of a short pointer fastened to the end of the photometer box.

The photometer head employed is of the Bunsen type. This type of head is especially suitable for our purpose be-

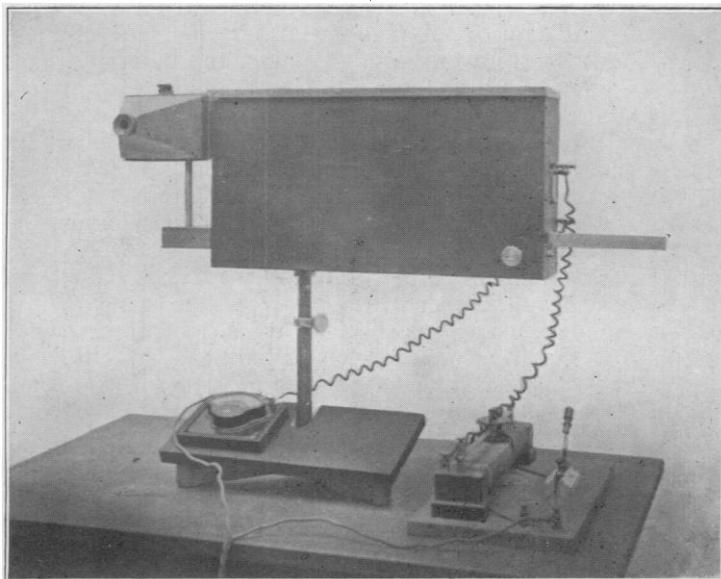


FIGURE II

cause it combines to a favorable degree the features of accuracy and simplicity of construction. The photometer screen may be very simply made. In the present case it consists merely of two pieces of Hering mat white paper 12.5 cm. long and 8 cm. wide smoothly pasted together with the mat side out. The screen so formed can be overlaid if desired with magnesium oxide deposited from the burning metal. In the median line (horizontal) of this screen, 1.5 cm. from one end a circular opening, 1.5 cm. in diameter, with serrated margins, is cut. This opening may be filled with a layer of an extra good grade of tissue paper or other translucent material, the edges of which are held between the two layers of Hering paper. It is desirable to have a material to fill this opening whose

coefficient of transmission is as nearly as possible equal to its coefficient of reflection. This screen fits into a groove which runs from front to back in the median plane of the photometer head. Set into the back of the photometer head on either side of the screen and making an angle of about 65 degrees with it are two mirrors of suitable size in which the images of the two sides of the screen are viewed by the eye in making the photometric comparison. On either side of the photometer head are two openings, 3.25 x 2.5 inches, for the illumination of the photometer screen. One of these admits the light from the standard lamp, the other the light from the room. Both of these openings are filled with a plate of single-thick milk glass (Belgian make) ground on one side. This glass diffuses the light and gives a more uniform illumination of the two sides of the photometer screen. In order that the two sides may be illuminated by light of the same color quality, color filters must be employed. That is, either the standard lamp must be robbed of its excess of yellow and red light or the daylight must be colored to match the light from the standard lamp. Either of these effects can be readily accomplished by means of thin sheets of colored gelatines, placed in the grooves in front of the sheets of milk glass. With gelatines of a low coefficient of selective absorption it is not at all difficult to make a good match of the two lights as to color quality and thus to eliminate the difficulty that attends the attempt to make a judgment of equality of brightness between two surfaces which differ as to color quality. In making this match by means of filters it must be remembered that if the match is made by filtering the daylight, a slight physical error will be introduced because of the variable composition of daylight on different days and at different times of the same day. That is, a filter that transmits heavily in the yellow will let a greater total of light through when the daylight contains an excess of yellow than when it does not. This objection, however, is considered by some photometrists to be of more theoretical than practical consequence. To offset this objection the greater photometric sensitivity to yellow may perhaps be mentioned with some justification. The variable composition of daylight also causes some difficulty in maintaining an exact color match between the standard light and daylight. A filter that produces an exact match at one time may not at another time. For this reason it is of advantage to make the filters of thin layers of gelatine which can be added to or subtracted from with the proper corrections for absorption as the need arises.

The bar carrying the standard lamp and the photometer

head is supported by a tripod base and stem. The stem consists of a hollow tube split at the upper end and fitted with a collar and set screw. The stem telescopes over a rod 8 inches long which is screwed into the photometer bar 8.5 inches from the end supporting the photometer head. By means of the collar and set screw the apparatus may be adjusted and clamped at different heights.

In order that the standard lamp may be operated directly from the line a rheostat and finely graduated ammeter are used to regulate and keep constant the supply of current. For the sake of portability the ammeter is fastened to a wood base which is screwed to two of the feet of the tripod. The ammeter is of Weston make, triple range, 0.5, 1, and 1.5 amperes, combined in one case. The scale of the first of these ranges is graduated to 0.01 amperes. On account of its size, its graduations, and its comparative inexpensiveness, this ammeter is very well suited for the purpose. A specification of the rheostat need not be given here. Any good rheostat of suitable carrying capacity and range of adjustment which permits of fine changes of resistance may be used.

The use of the apparatus for the reproduction of any given illumination is as follows: The rheostat is adjusted to give the amperage at which the standard lamp is to be operated. A balance is then made at the point in the room in question between the light falling on the photometer head and the standard light, and a reading is taken of the photometer scale. When it is wished to reproduce this illumination the resistance is again adjusted to give the reading of the ammeter chosen as standard and the light of the room is varied until a photometric match is obtained. If it is wished to calibrate the instrument so that the reading of the scale can be translated into foot-candles, for example, a standard lamp is set up at such distance from the milk glass test plate on the photometer head as will give a balance with the photometer lamp adjusted for the different points on the scale. The amount of light falling on the test plate can be computed directly from the known flux of the standard lamp and the distance of the lamp from the test plate. This is correlated with the division on the scale for which the photometric balance is made. The different points on the scale are thus gone over one by one and the correlative foot-candle values are obtained. During the calibration the photometer lamp must of course be operated at a constant amperage, and in the use of the calibrated instrument this amperage must be reproduced else the calibrated values will not be valid.